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Improved Cost and Performance of PFAS Groundwater Treatment using a Carbon-Based Micro-adsorbent and Ceramic Separations Technology

Terence Reid, P.E. - Aqua-Aerobic Systems, Inc. treid@aqua-aerobic.com

Joseph Quinnan, P.E. – Arcadis U.S. joseph.quinnan@arcadis.com

Vivek Pulikkal, PhD. – Arcadis U.S. Vivek.Pulikkal@arcadis.com

Christopher Bellona, PhD. – Colorado School of Mines cbellona@mines.edu

ARCADIS Design & Consultancy for natural and built assets

AQUA-AEROBIC SYSTEMS, INC. A Metawater Company

COLORADOSCHOOLOFM EARTH ENERGY ENVIRON

ESTCP

Technical Objectives

Demonstrate and validate application of the Micro-Adsorbent/Membrane treatment approach to reduce the total life cycle cost of PFAS-impacted groundwater treatment by evaluating:

1) Broad spectrum and short-chain PFASs treatment selectivity;
2) PFAS treatment performance in presence of co-contaminants common at DoD Fire Training Areas; and,
3) Cost and performance requirements related to concentration and treatment of the retentate.


ESTCP

IMPROVED LONGEVITY AND SELECTIVITY OF PFAS GROUNDWATER TREATMENT USING SUB-MICRON POWDERED ACTIVATED CARBON (SPAC) AND CERAMIC MEMBRANE FILTRATION (CMF)

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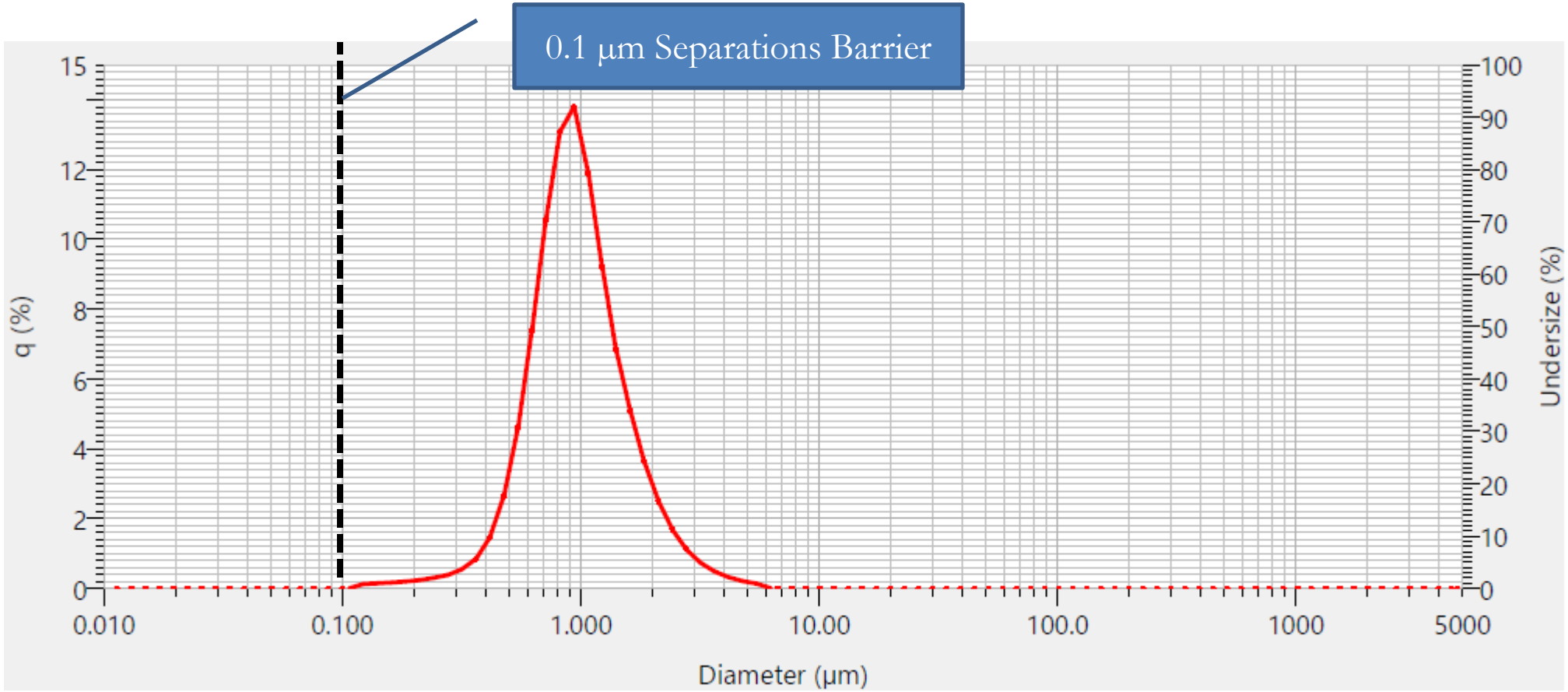
Version 2
Joseph Quinnan, Arcadis
Terence Reid, Aqua-Aerobic Systems, Inc.
Vivek Pulikkal, Arcadis
Chris Bellona, Colorado School of Mines

December 2022

Environmental Security Technology Certification Program (ESTCP)

AquaPRS™ PFAS Removal Technology

Micro-adsorbent

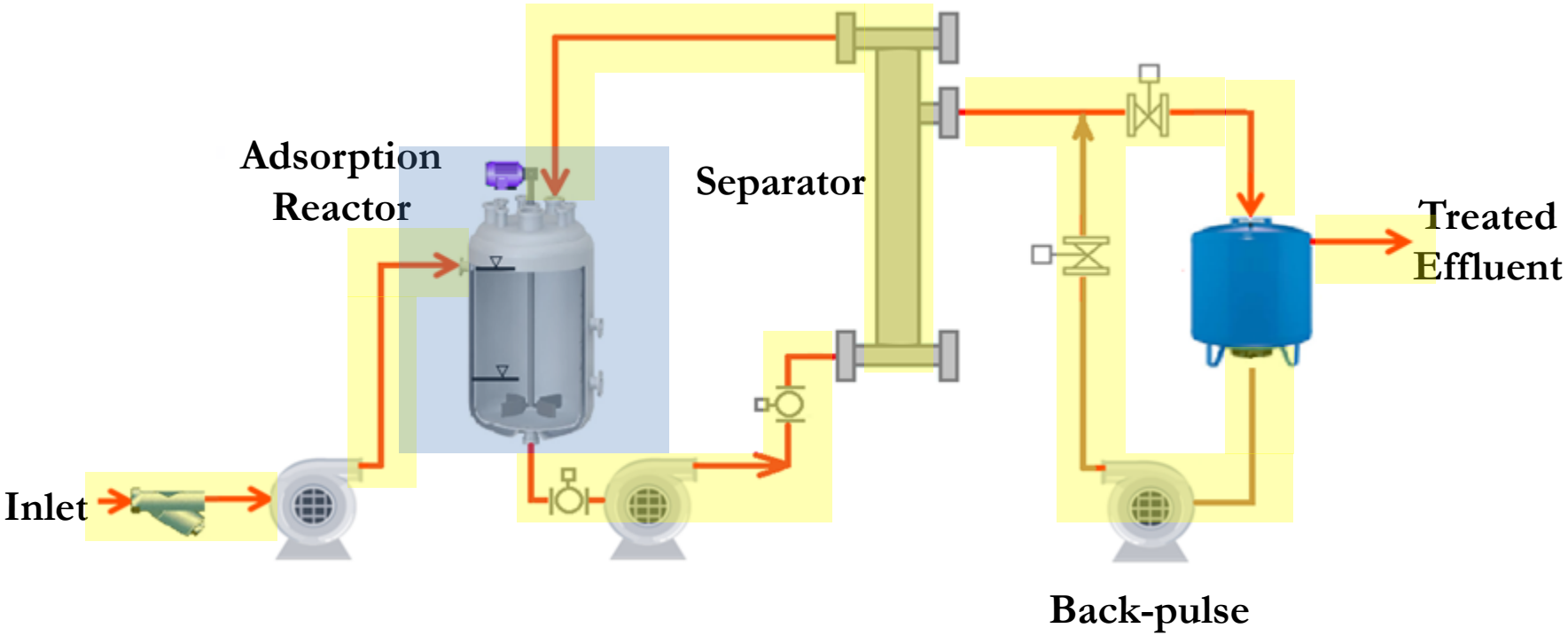


AquaPRS PFAS Removal Technology

Micro-adsorbent

AquaPRS Technology

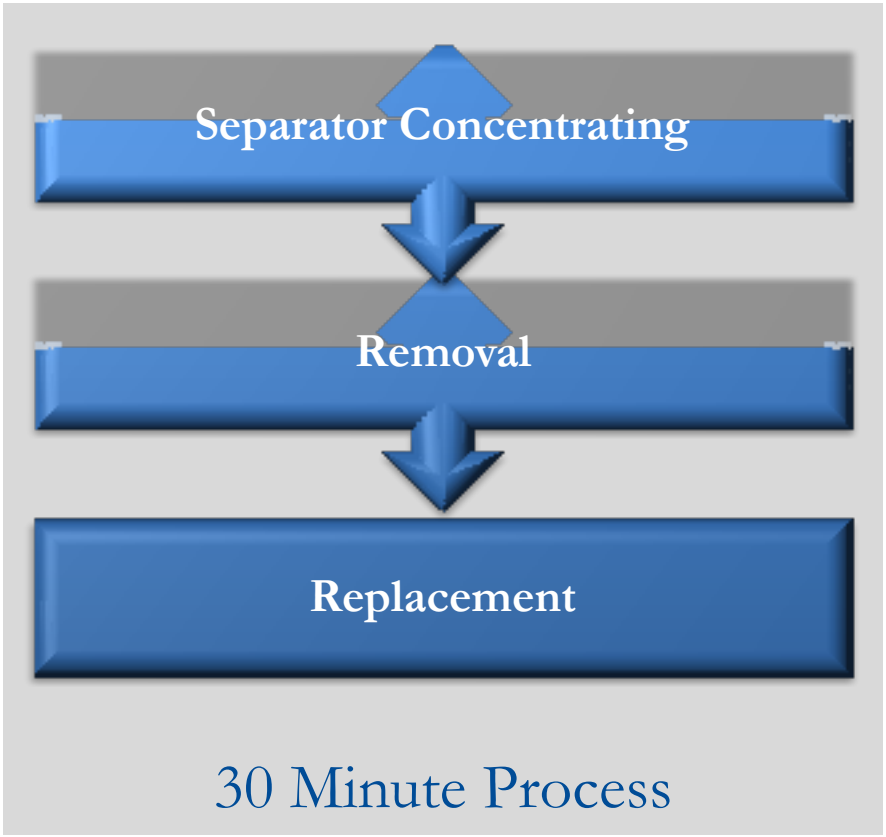
System Layout



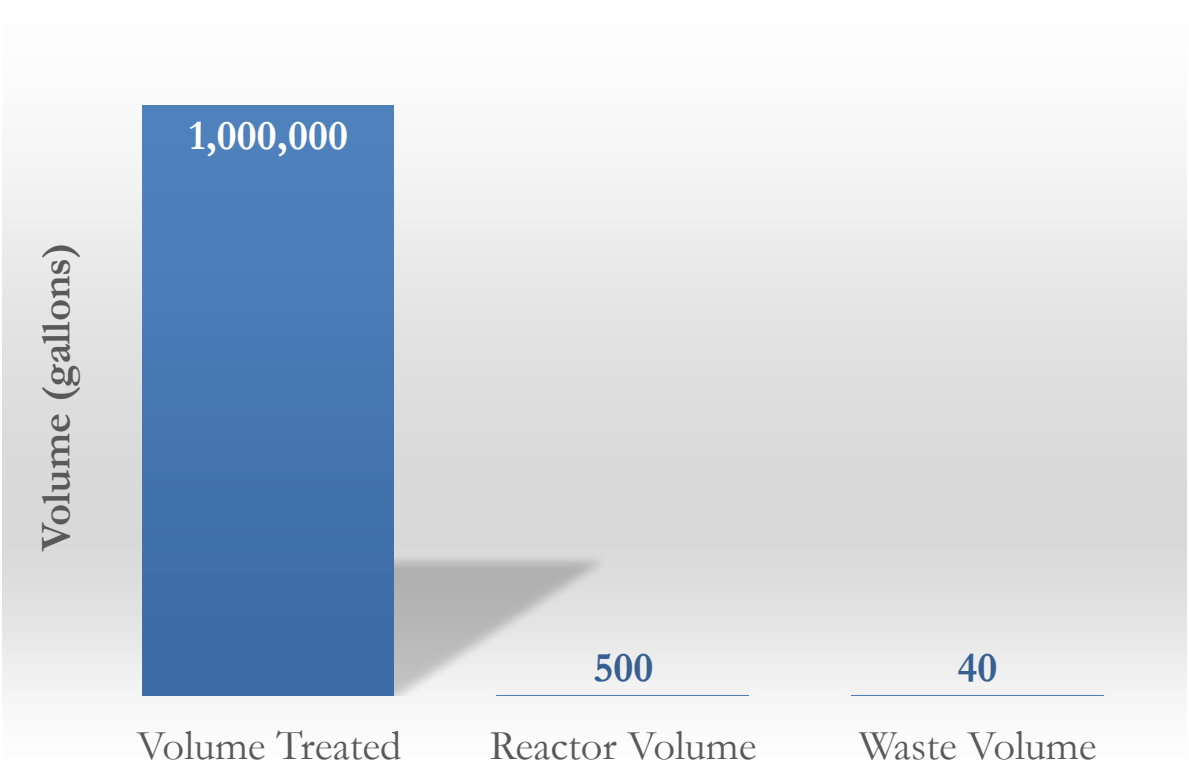
- Sorbent is Batch Loaded
- 2-4% Solids
- 1-4 week replacement interval
- No waste between replacements

Waste Disposal

Thickening Prior to Replacement



30 Minute Process



100 gpm example: 7-Day Replacement

SERDP DOD • EPA • DOE | ESTCP

DoD's Environmental Research Programs

Horsham AGS: Surface Water

Willow Grove NAS: Groundwater

Horsham Air Guard Station

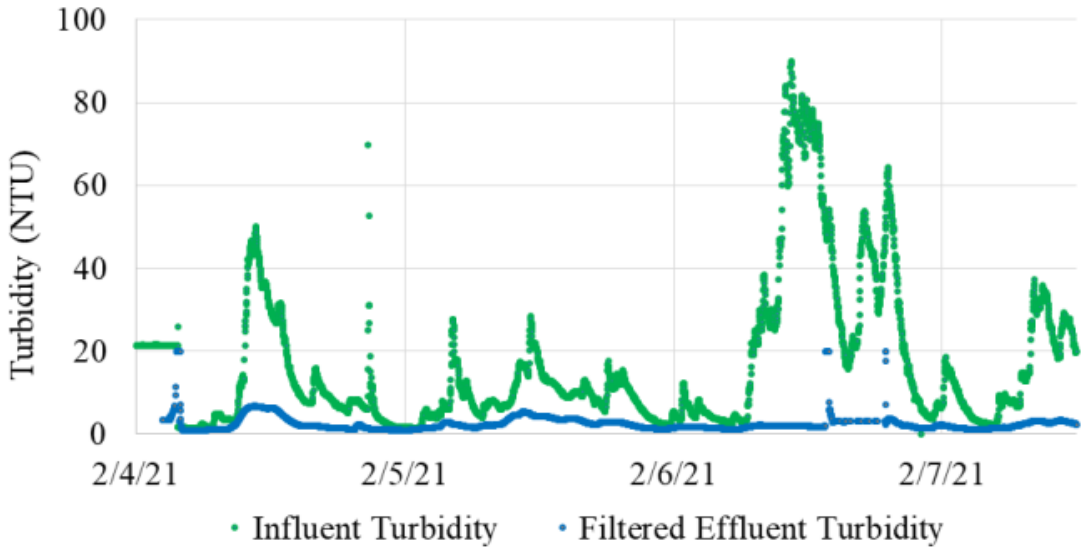
Performance Assessment – Surface Water

June 2020 – March 2021

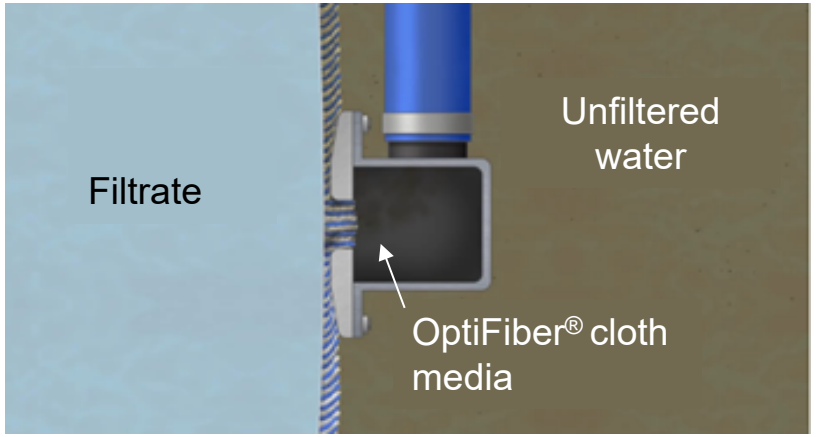
Surface Water Treatment

Pre-Treatment Requirement

- Influent turbidity = 1 to 100 NTU
- Influent TOC = 2 to 4 mg/L
- Filter effluent turbidity = 1 to 4 NTU
- Final turbidity = 0.04 to 0.06 NTU



Cloth Media Filter



Horsham Performance Assessment

Test Conditions

In Summary:

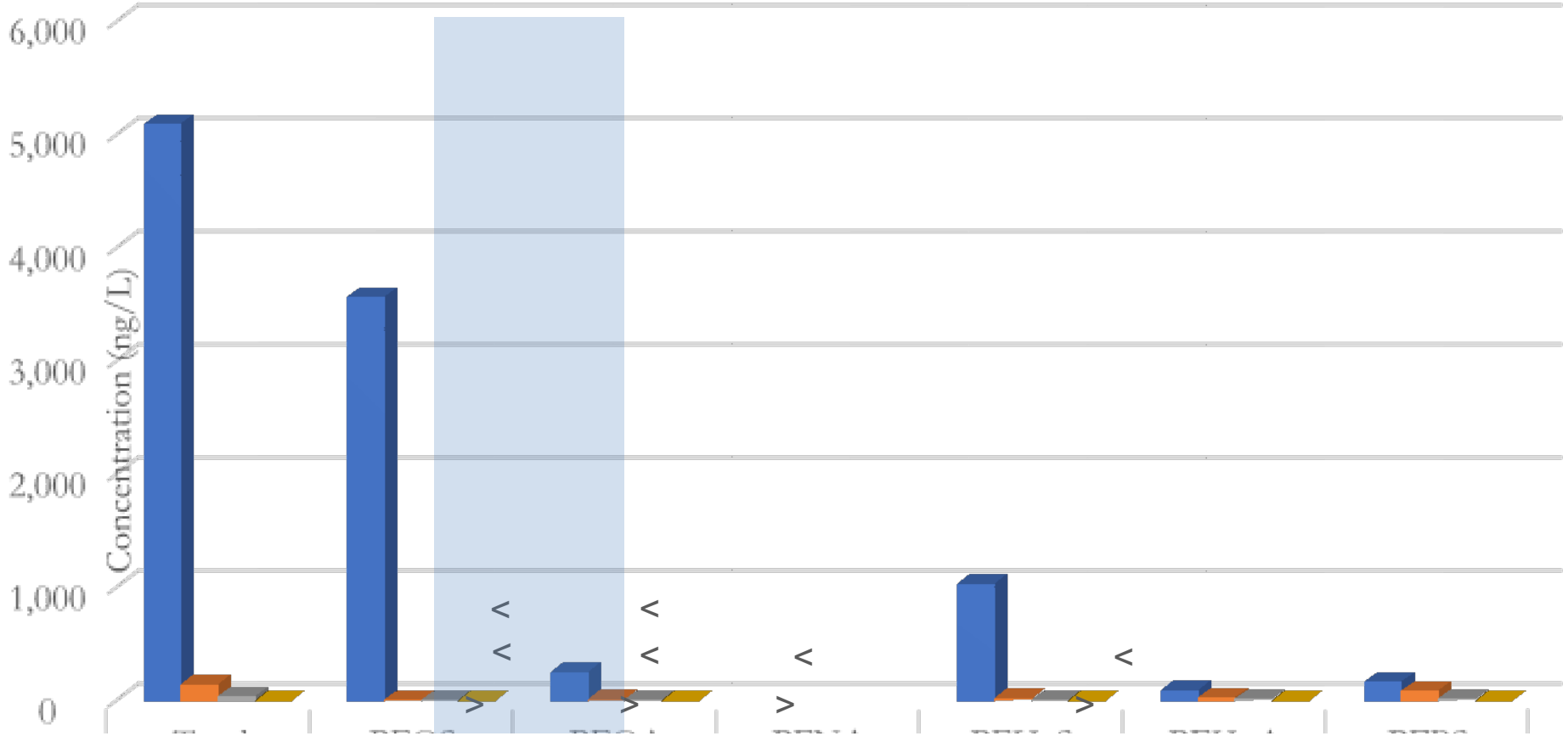
- 2 Trains (A & B)
- 13 Tests
- 2 Conditions/Test
- 1 & 2 Stage
- Quantify Performance

Table 8. Test Conditions Evaluated at the Horsham AGS Pilot Study.

Test	Operating Mode	Hydraulic Detention Time (min)	Sorbent Mass (g)	Sorbent Density (g/L)	Flow Rate (L/min)
1A	1-Stage	60	20	0.5	0.67
1B	1-Stage	60	10	0.25	0.67
2A	1-Stage	120	20	0.5	0.33
2B	1-Stage	120	10	0.25	0.33
3A	1-Stage	60	10	0.5	0.33
3B	1-Stage	60	20	0.5	0.67
4A	1-Stage	30	70	3.5	0.7
4B	1-Stage	15	35	3.5	0.7
5A	1-Stage	30	70	3.5	0.7
5B	1-Stage	30	40	2	0.7
6A	1-Stage	60	200	5	0.7
6B	1-Stage	40	200	5	1.0
7A	1-Stage	20	300	15	1.0
7B	1-Stage	5	75	15	1.0
8A	1-Stage	20	430	21.5	1.0
8B	1-Stage	5	430	86	1.0
9A	1-Stage	20	200	10	1.0
9B	1-Stage	5	200	40	1.0
10A	1-Stage	20	200	10	1.0
10B	1-Stage	5	200	40	1.0
11A	1-Stage (lead)	5	200	40	1.0
11B	2-Stage (lag)	7.5	200	40	0.7
12A	1-Stage (lead)	7.5	200	40	0.67
12B	2-Stage (lag)	5	200	40	0.1
13A	2-Stage (lag)	5.4	200	40	0.93
13B	1-Stage (lead)	5	200	40	1

AquaPRS Technology

Horsham Surface Water Treatment

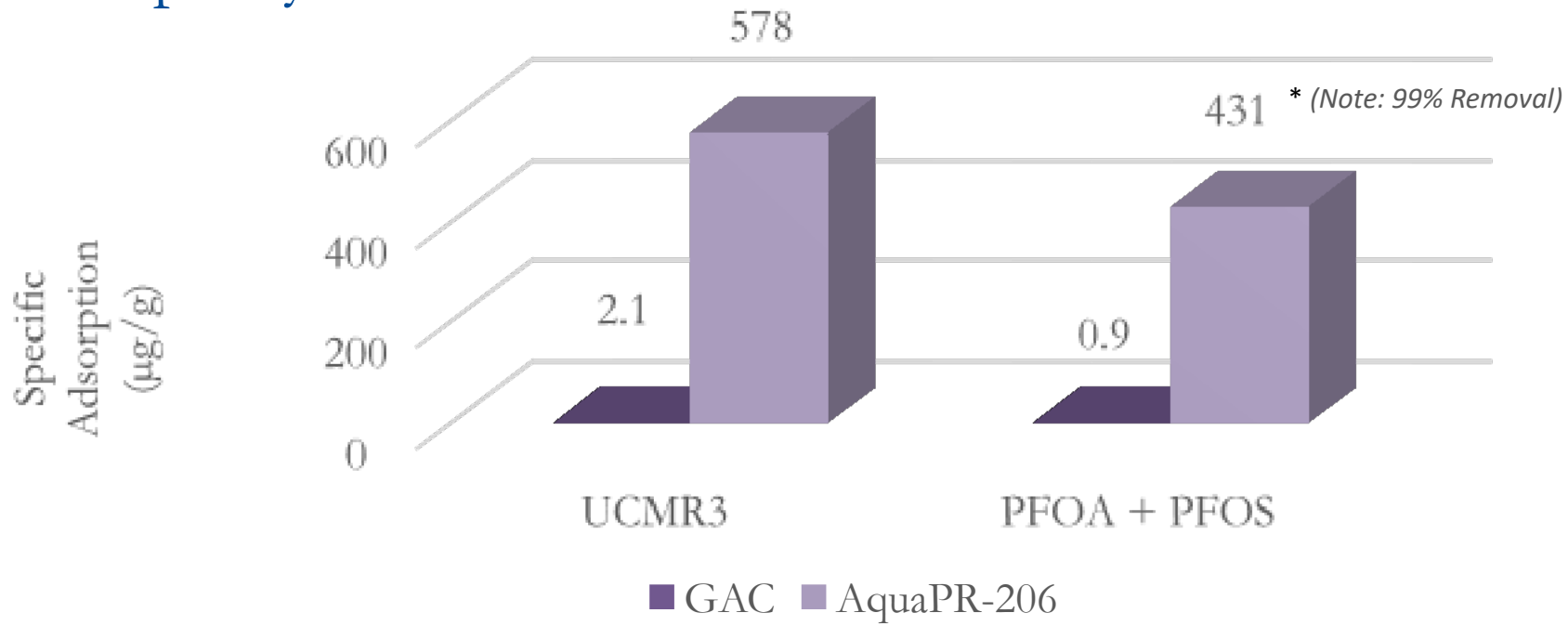


Dual Stage Treatment

All UCMR3 Compounds < 40 ng/L (combined)

AquaPRS Technology

Adsorption Capacity vs. GAC



AquaPR-206 sorbent material ~400 times more effective than GAC

*Comparison based on 10% breakthrough as GAC was not able to achieve project effluent limits (40 ng/L UCMR3 or 70 ng/L combined PFOA, PFOS)

Cost Assessment – Horsham Example

100 gpm treating 6,000 ng/L PFOS & PFOA < 70 ng/L

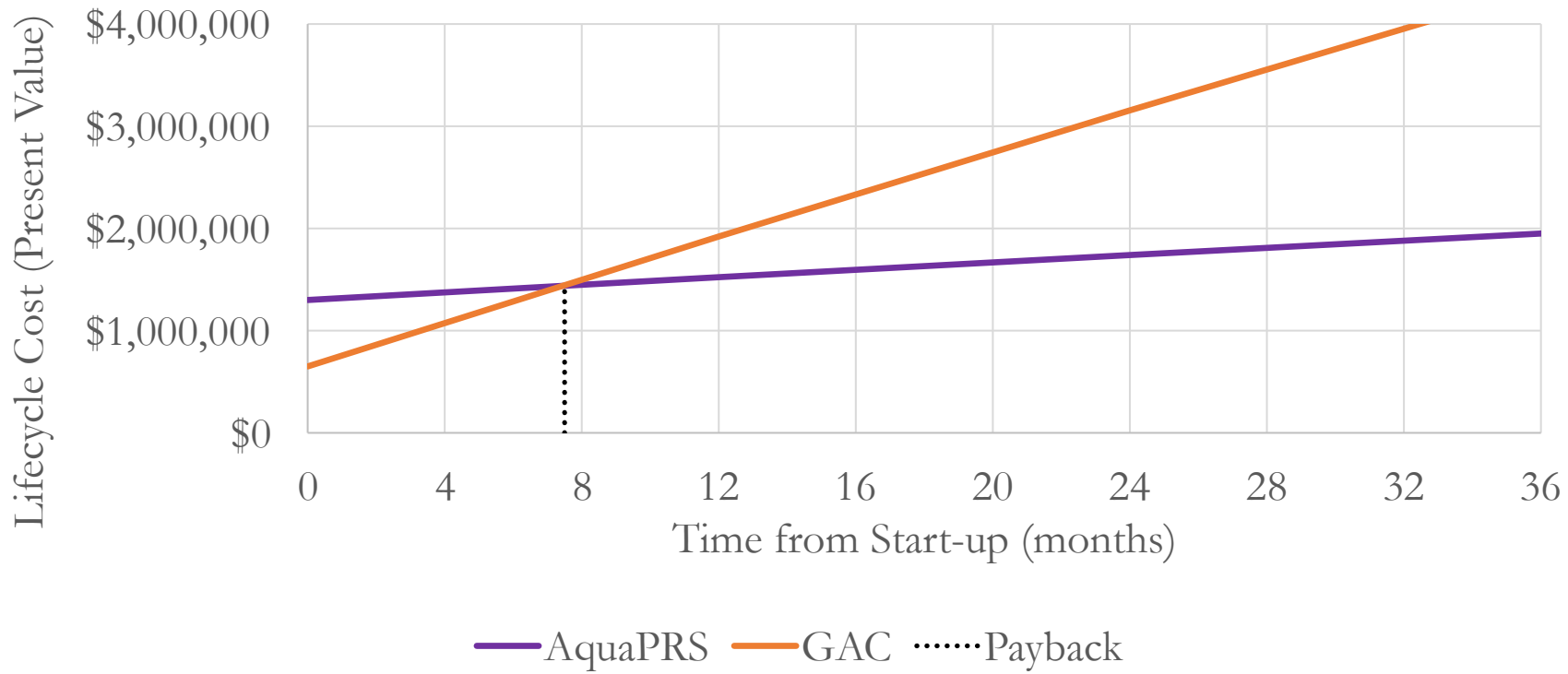
			AquaPRS		GAC
Capital	Equipment	$	800,000	$	50,000
	Construction	$	500,000	$	500,000
O&M	Media Supply	$	143,114	$	1,231,202
	Service	$	2,400	$	2,400
	Power	$	1,584	$	660
	Chemicals	$	-	$	-
	Monitoring & Compliance	$	75,000	$	75,000
	Replacement Parts	$	-	$	-
	Disposal	$	7,775	$	-
Lifecycle Cost[1]		**$**	**4,719,936**	**$**	**20,128,507**

[1]20-year Present Value based on 3% annual rate of return

~80% Cost Savings over 20-years

Cost Assessment – Horsham Example

100 gpm treating 6,000 ng/L PFOS & PFOA < 70 ng/L



Less than 8-month payback period compared to GAC

Notes: Horsham Air Guard Station (HAGS) water quality characteristics: 6,000 ng/L to <70 ng/L effluent PFOA + PFOS. GAC adsorption rates were applied higher than RSSCT demonstrated.

Willow Grove Naval Air Station

Performance Assessment – Ground Water

May – October 2021

Willow Grove Performance Assessment

Test Conditions

In Summary:

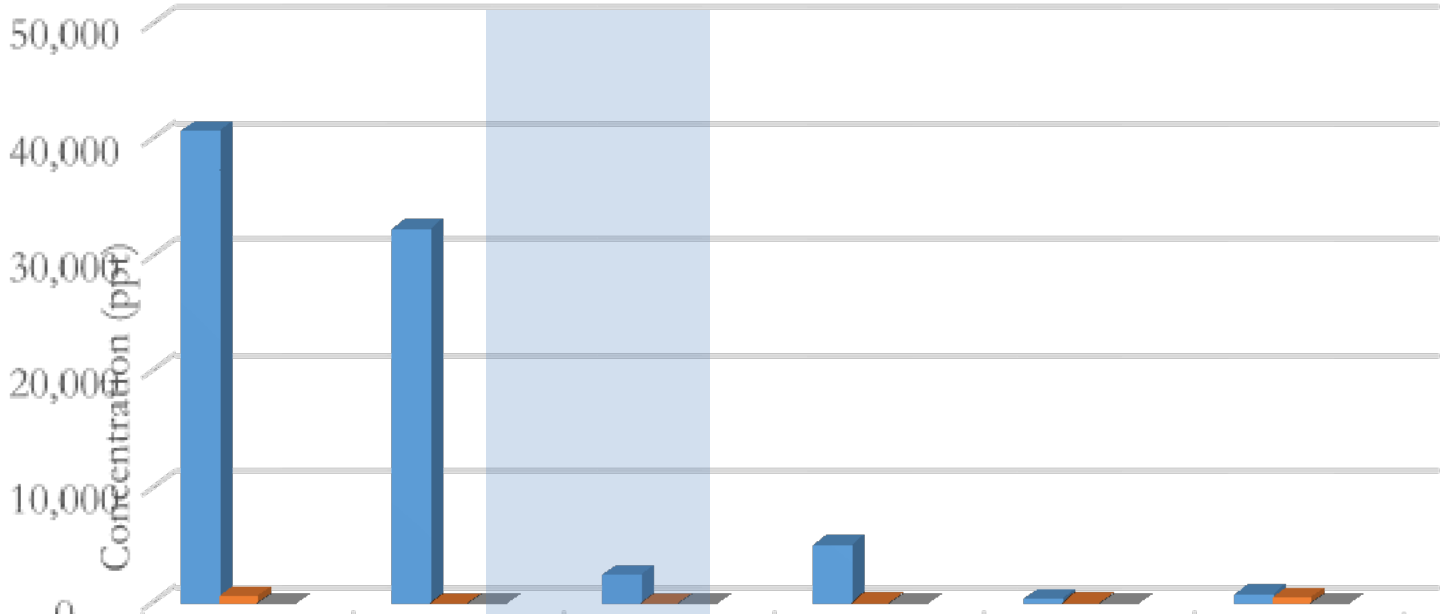
- 5 Tests
- 2 Conditions/Test
- 1 & 2 Stage
- Quantify Performance
- Sorbent Comparison

Table 16. Test Conditions Evaluated at the Willow Grove NAS Pilot Study.

Test Condition	Operating Mode	Hydraulic Detention Time (min)	Sorbent Mass (g)	Sorbent Density (g/L)	Flow Rate (L/min)
1A	1-Stage	20	200	10	1.0
1B	1-Stage	10	200	20	1.0
2A	1-Stage	8	200	25	1.0
2B	1-Stage	16	200	12.5	1.0
3A	2-Stage (lead)	10	100	10	1.0
3B	2-Stage (lag)	10	100	10	0.9
4A	2-Stage (lag)	10	100	10	0.9
4B	2-Stage (lead)	10	100	10	1.0
5A	1-Stage	10	200	20	0.67
5B	1-Stage	10	200	20	0.67

AquaPRS Technology

Willow Grove Ground Water Treatment



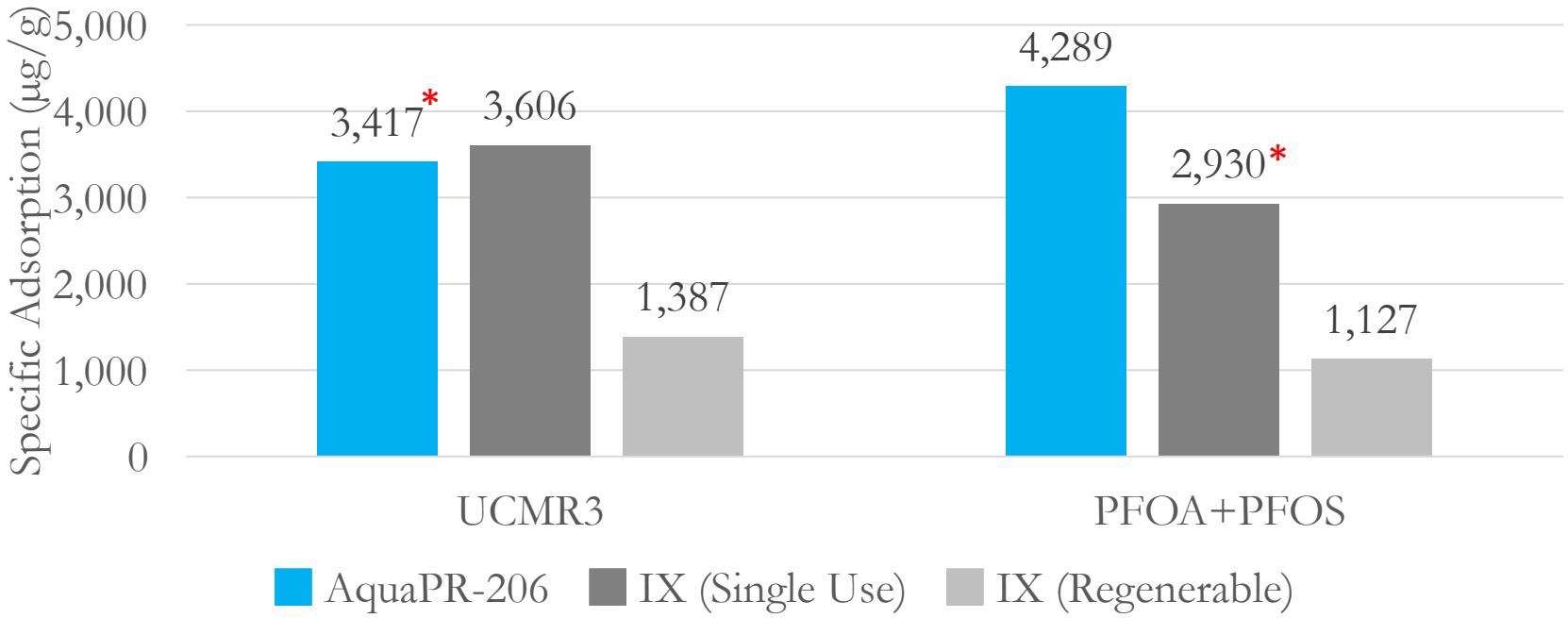
	Total (ng/L)	PFOS (ng/L)	PFOA (ng/L)	PFHxS (ng/L)	PFHpA (ng/L)	PFBS (ng/L)
Influen	40,630	32,194 <	2,391	4,996 <	314 <	736 <
Effluent Lead (A)	586	22 >	15	52 >	37 >	461 >

Dual Stage Treatment

All UCMR3 Compounds < 40 ng/L (combined)

AquaPRS Technology

Adsorption Capacity vs. Ion Exchange



AquaPR-206 sorbent material among highest adsorptive capacities of best performing IX Resins

*Denotes Breakthrough Threshold Not Reached and SAR may be higher

Cost Assessment – Willow Grove Example

20 gpm treating 38,000 ng/L UCMR3 Compounds

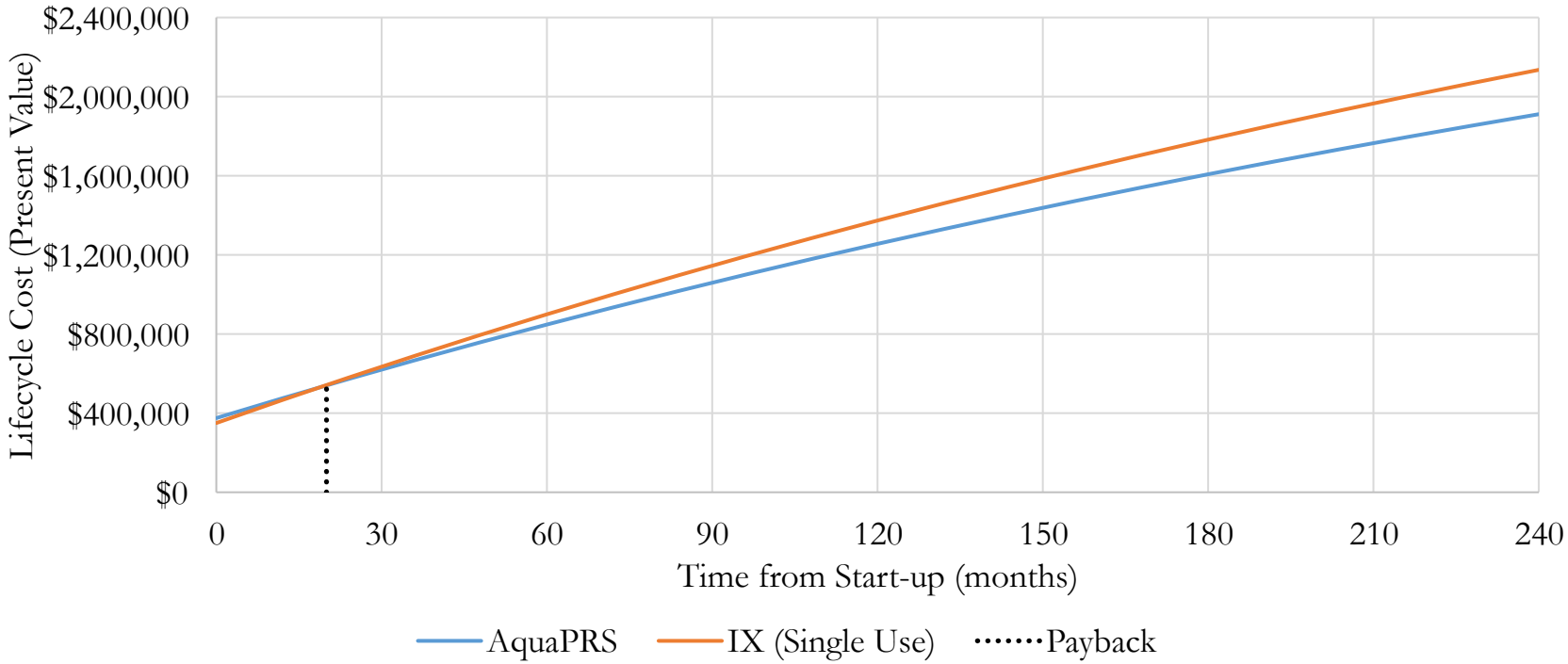
			AquaPRS		IX (Single Use)
Capital	Equipment	$	275,000	$	250,000
	Construction	$	100,000	$	100,000
O&M	Media Supply	$	24,219	$	41,590
	Service	$	2,400	$	2,400
	Power	$	317	$	183
	Chemicals	$	-	$	-
	Monitoring & Compliance	$	75,000	$	75,000
	Replacement Parts	$	-	$	-
	Disposal	$	1,316	$	837
Lifecycle Cost[1]		**$**	**1,911,128**	**$**	**2,135,445**

[1]20-year Present Value based on 3% annual rate of return

~10% Cost Savings over 20-years against Best Performing IX Resin

Cost Assessment – Willow Grove Example

20 gpm treating 38,000 ng/L UCMR3 Compounds



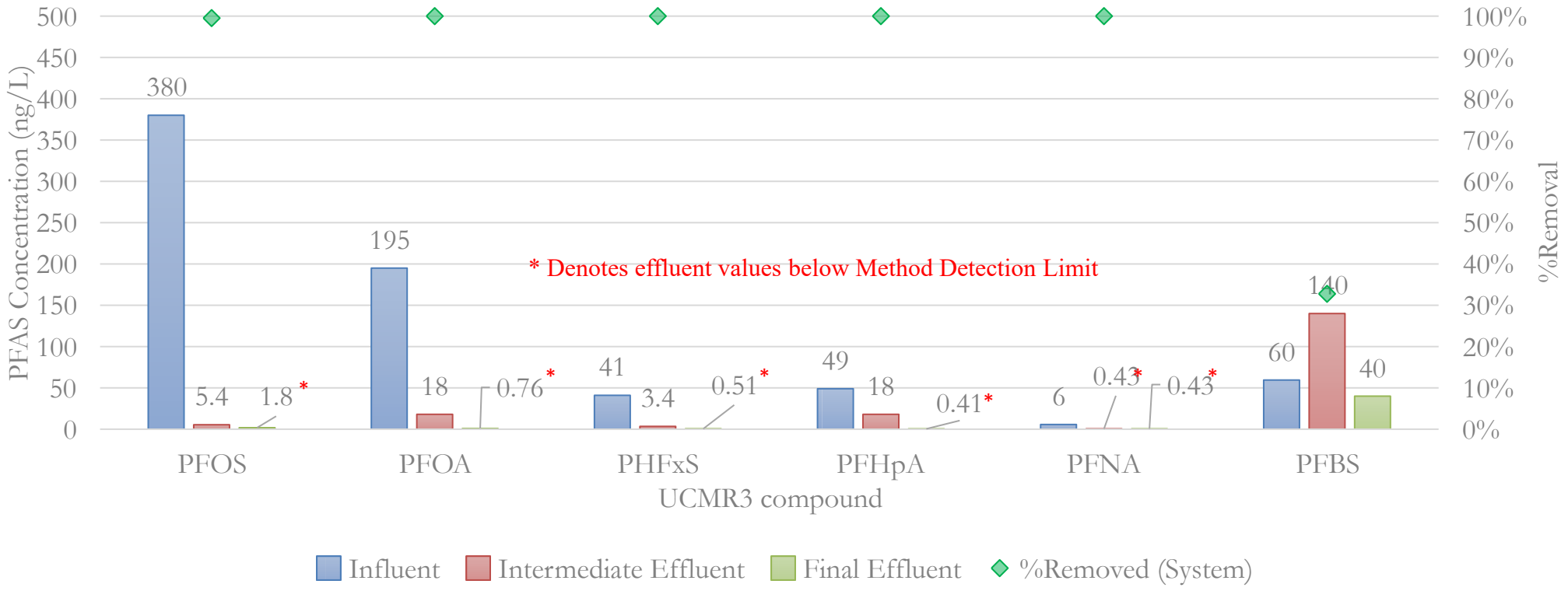
2-year payback period compared to Single Use Resin

Notes:

1. Based on Test 3 data at Willow Grove for AquaPRS and compared with results from prior study (Ellis et. al 2022) using the best performing IX resin of five studied at Willow Grove
2. Effluent target based on Regional Screening Level (4 ng/L PFOS, 6 ng/L PFOA, PFNA and HFPO-DA, 39 ng/L PFHxS and 601 ng/L PFBS).

AquaPRS™ Technology Applications

Reverse Osmosis Concentrate – Municipal (Surface) Water



PFOS, PFOA < 4 ppt

Hazard Index MCLG = $\sum$ ($PFAS_{water}$)/$PFAS_{HBWC}$) = 1.0

HI MCLG = [$GenX_{water}$/10 ng/L] + [$PFBS_{water}$/2000 ng/l] + [$PFNA_{water}$/10 ng/L] + [$PFHxS_{water}$/9 ng/L] = 1.0

AquaPRS Implementation

Small-Scale Pilot Test Units

	PFOS			PFOA		
Willow Grove Test	Influent (ng/L)	Effluent (ng/L)	Adsorption (µg PFAS/g Sorbent)	Influent (ng/L)	Effluent (ng/L)	Adsorption (µg PFAS/g Sorbent)
Lab Pilot	33,000	< LOQ	1,146	3,400	12	118
Test 1A	24,333	38	1,636	2,967	70	169
Test 1B	24,333	59	1,648	2,967	46	197

Factory Testing Matched Field Test Results

- Production Level Sorbent and Separator
- Automated
- Simulates one complete replacement Interval (< 2 weeks)
- On-site or Factory Testing

Pilot System (150 L/day)

AquaPRS Technology

PFAS Treatment Summary

- 400x more adsorbent than GAC
- Lifecycle Cost Advantage over GAC, RO and Ion Exchange
- Flexible Operations:
  - Adjustable sorbent levels
  - Automatic sorbent replacement (< 1 hour)
  - High quality (particulate free) effluent
  - Single or dual-stage capabilities

Acknowledgements

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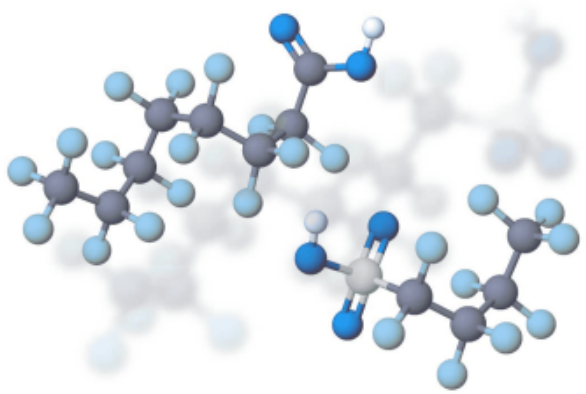
- Jason Speicher – NAVFAC Atlantic



Thank You!

Questions?

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